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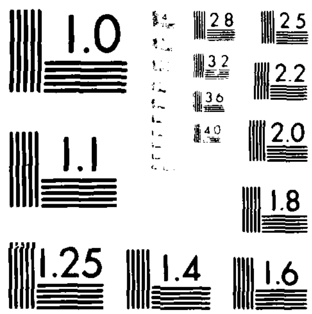

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FINAL REPORT

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SUPPLEMENTAL STUDY: SURGE-PERIOD SHELTER PROGRAMS

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This report describes a continuation of an earlier study of the feasibility and costs of providing all-effects shelters in risk areas for an in-place shelter plan and a population relocation plan. The results of the earlier study indicated that a minimum of 6 months and 50 percent of national production of reinforcement and plate steel would be required to provide shelters for the population of risk areas for an in-place shelter plan. The

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purpose of the study described herein was to determine if advanced purchase and storage of materials would be a realistic measure for improving surge period shelter building capability.

The results of the study show that there are three feasible programs for storing materials to support surge period shelter construction. Under the assumptions used in the study, the overall program cost is not significantly increased by the storage of materials. However, there may be severe shortages of labor to implement a surge period shelter program.

ABSTRACT

This report describes a continuation of an earlier study of the feasibility and costs of providing all-effects shelters in risk areas for an in-place shelter plan and a population relocation plan. The results of the earlier study indicated that a minimum of 6 months and 50 percent of national production of reinforcement and plate steel would be required to provide shelters for the population of risk areas for an in-place shelter plan. The purpose of the study described herein was to determine if advanced purchase and storage of materials would be a realistic measure for improving surge period shelter building capability.

The results of the study show that there are three feasible programs for storing materials to support surge period shelter construction. Under the assumptions used in the study, the overall program cost is not significantly increased by the storage of materials. However, there may be severe shortages of labor to implement a surge period shelter program.

TABLE OF CONTENTS

LIST OF TABLES

PREFACE

This report describes the continuation of an earlier study entitled Feasibility and Cost Analysis of Surge-Period Shelter Programs published in June 1980. The reader is referred to the earlier study for details of the data base development, analytical techniques, and additional information on the work described herein.

I. INTRODUCTION

In a recent study for the Federal Emergency Management Agency (FEMA) entitled Feasibility and Cost Analysis of Surge-Period Shelter Programs [1], the Research Triangle Institute (RTI) investigated several options for constructing all-effects shelters for selected fractions of the resident population of risk areas. The study considered six shelter designs that FEMA selected and evaluated the feasibility and costs of shelter-building programs on a surge basis. The fraction of the population to be housed, the surge period length, and the resources available for shelter construction programs were varied to generate different scenarios. Results of the analyses indicate that, for some scenarios, availability of materials is the factor that limits the number of shelters and that increased availability of these materials could improve the shelter-building capability.

Based on these results, a task was initiated to investigate the impact of changes in availability of materials on shelter-building capability. Increased availability of materials can be achieved through either increased production or advanced storage of the materials. Because production increases are limited by available industrial capacity, material storage could be an important factor in implementing a surge period shelter construction program.

This report describes an investigation of the effects of material storage on surge period shelter construction programs and presents recommendations regarding the need for and cost of material storage for these programs. The study is a follow-on to the work cited above as Reference 1 and uses the analytical procedures and data base developed in that study.

II. APPROACH

The overall approach to investigating effects of material storage on risk area shelter programs is basically the same as was used in the earlier study described in Reference 1. In that study, a linear programming model was developed which indendently used two objective functions. The first objective function was used to determine the maximum number of shelters that could be built subject to several sets of constraints on the availability of resources and the time available for shelter construction. Independent evaluations were made with resource availabilities ranging from 10 to 50 percent of total production and for time periods (surge period lengths) ranging from 3 to 12 months.

The second objective function was used to determine the minimum cost of providing shelters for selected fractions of the risk area population, subject to the same constraints on resource availability and surge period length. Evaluations were made for fractions of the risk area population ranging from 2.31 to 100 percent. The 2.31-percent figure represents the critical work force that would probably remain in the risk area in a crisis relocation situation.

After the earlier study was completed, the RTI investigators identified a refinement that could make the linear programming model more realistic. Prior to the current investigation, this refinement was incorporated into the model. The change and its rationale are described below.

A. Model Modification

As originally written, the linear programming model considered a surge period to be a single time interval regardless of actual time covered. Thus, all materials and all labor and equipment hours were considered available at

any time they were needed throughout the surge period. In reality, materials would be delivered periodically throughout the surge period as production permitted, while labor and equipment would be available at a constant level throughout the surge period. The results obtained from the original model are realistic if the delivery schedule for materials is compatible with the availability of labor and equipment. However, if one shipment of materials is exhausted before the next shipment arrives, the equipment and labor hours available during the idle time are lost and cannot be recovered. Because the earlier study indicated that labor and equipment were in short supply, RTI analysts concluded that a surge period should be considered as the sum of several shorter time intervals rather than a single time interval. A daily analysis seemed most appropriate for accurately reflecting the availability of labor and equipment. However, daily material shipments appear unlikely and the use of such a short time interval would become cumbersome in evaluating surge period lengths of up to a year. After a careful evaluation of the parameters involved and consideration of the knowledge gained from discussions with individuals connected with the industries involved in material production, RTI selected 1 month as a reasonable time interval between material shipments.

The linear programming model was revised in light of the above line of reasoning. For the revised model, a surge period is considered to be a series of monthly time intervals rather than a single time interval. During the analysis, if materials remain unused at the end of 1 month, they are carried to the next month. If labor and/or equipment are unused during 1 month, they are considered lost and cannot be recovered or carried to the next month. Revisions to the model do not change the total materials available during a surge period: they only provide a more realistic evaluation of the

compatibility of the availability of equipment and labor with the availability of materials. Results produced by the revised model are identical to those produced by the original model if labor and equipment are plentiful.

B. Model Formulation

The formulation of the revised model is basically the same as that of the original model except for the revision described above pertaining to treatment of the surge period. The effect of the revision on the model formulation was to add a summation to the equations for the objective functions and to the constraint equations. The new summation represents the summary of results obtained from the analysis of each monthly period. The revised equations are presented below. The first objective function is as follows:

$$\text{Maximize } Z = \sum_{i=1}^{n} \sum_{m=1}^{t} C_i X_{i,m} ,$$

Subject to

$$\sum_{i=1}^{n} \sum_{m=1}^{t} a_{i,j} X_{i,m} \leq \sum_{m=1}^{t} M_{j,m} \quad \text{for } j=1 \text{ to } p$$

$$\sum_{i=1}^{n} \sum_{m=1}^{t} b_{i,k} X_{i,m} \leq \sum_{m=1}^{t} L_{k,m} \quad \text{for } k=1 \text{ to } q$$

$$\sum_{i=1}^{n} \sum_{m=1}^{t} d_{i,l} X_{i,m} \leq \sum_{m=1}^{t} E_{l,m} \quad \text{for } l = 1 \text{ to } r$$

$$\sum_{i=1}^{n} a_{i,j} X_{i,m} \leq M_{j,m} + [M_{j,m-1} - \sum_{i=1}^{n} a_{i,j} X_{i,m-1}] \quad \text{for } j=1 \text{ to } p,\ m=1 \text{ to } t$$

$$X_{i,m} \geq 0$$

where

Z = total number of shelter spaces,

n = total number of shelter types,

i = shelter type (i=1 to n),

p = total number of material types,

j = material type (j=1 to p),

q = total number of labor types,

k = labor type (k=1 to q),

r = total number of equipment types,

l = equipment type (l=1 to r),

t = total number of monthly periods,

m = study period (m=1 to t),

C_i = capacity of shelter type i,

$X_{i,m}$ = number of shelters of type i built in time period m (the decision variable),

$a_{i,j}$ = amount of materials of type j required for a unit shelter of type i,

$b_{i,k}$ = amount of labor hours of type k required for a unit shelter of type i,

$d_{i,l}$ = amount of equipment hours of type l required for a unit shelter of type i,

$M_{j,m}$ = amount of material of type j available in time period m,

$L_{k,m}$ = amount of labor hours of type k available in time period m, and

$E_{l,m}$ = amount of equipment hours of type l available in time period m.

The second objective function is as follows:

$$\text{Minimize } z_1 = \sum_{i=1}^{n} \sum_{m=1}^{t} c_i X_{i,m} \quad ,$$

Subject to

$$\sum_{i=1}^{n} \sum_{m=1}^{t} a_{i,j} X_{i,m} \leq \sum_{m=1}^{t} M_{j,m} \quad \text{for } j=1 \text{ to } p$$

$$\sum_{i=1}^{n} \sum_{m=1}^{t} b_{i,k} X_{i,m} \leq \sum_{m=1}^{t} L_{k,m} \quad \text{for } k=1 \text{ to } q$$

$$\sum_{i=1}^{n} \sum_{m=1}^{t} d_{i,l} X_{i,m} \leq \sum_{m=1}^{t} E_{l,m} \quad \text{for } l=1 \text{ to } r$$

$$\sum_{i=1}^{n} \sum_{m=1}^{t} C_i X_{i,m} \geq P \quad ,$$

$$\sum_{i=1}^{n} a_{i,j} X_{i,m} \leq M_{j,m} + [M_{j,m-1} - \sum_{i=1}^{n} a_{i,j} X_{i,m-1}] \quad \text{for } j=1 \text{ to } p, \; m=1 \text{ to } t$$

$$X_{i,m} \geq 0$$

where

z_1 = total cost of a shelter program,

c_i = costs of shelter type i, and

P = the population to be sheltered.

C. Model Capabilities

With the first objective function defined above, the maximum number of shelter spaces that can be built under any combination of constraints on time and resources can be estimated. When a problem is solved, the result indicates the:

- Maximum number of shelter spaces that can be built,
- Types of shelters that should be built to obtain this maximum value, and
- Quantity of each resource needed.

Sensitivity analyses can be conducted by solving a problem repeatedly with different constraints on the availability of time and resources. Constraints can be added to or deleted from the analysis as desired.

With the second objective function defined above, the minimum cost of constructing a specified number of shelter spaces can be determined under any selected combination of constraints on the availability of time and resources. If the specified number of shelters cannot be built within time and resource constraints, results of the analysis will indicate that no solution to the problem is feasible. If a solution is feasible, the program will indicate the combination of shelter types that could provide the specified

number of shelter spaces at the least cost. It will also identify the number of each type of shelter to be built, the quantity of each resource needed, and the associated total cost of the shelter program. Constraints can be added or deleted as desired to determine their impacts on the shelter construction program.

D. Data Requirements and Sources

Data requirements are the same for the revised model and the original model. These requirements include:

- Materials, labor, and equipment needed to construct each of the six shelter types considered in the study;
- Total annual production of each material needed;
- Total amount of labor and equipment available;
- Cost of each resource used; and
- Total risk area population.

All of these data were collected as part of the earlier study and are described in detail in Reference 1. The reader is referred to that report for details on the sources of information and the procedures used to develop the data base.

New information pertaining to the availability and cost of storage space was obtained for this study to investigate the effects of material storage on shelter construction. This information was obtained from a recent study by the Defense Logistics Agency (DLA) [2], which investigated the availability of storage space to support a shelter program. In that study, use of DLA-operated warehouses and military installations was emphasized. Study results showed that the storage space requirements of the shelter program are extremely small relative to the space available. Therefore, the availability of storage space was not concluded to be a problem.

A second aspect of material storage that must be considered is cost. The DLA report referenced above indicates no charge would be levied for space contained in DLA warehouses and military installations for the storage of materials to support a shelter program. Subsequent discussions with DLA representatives revealed that a one-time charge of $12.70 per ton is assessed for placing materials into storage. This figure was used in the current study as the total cost of a material storage program, and all of the cost data contained in the results section of this report include that charge. Consequently, feasibility and cost conclusions regarding the shelter-building programs depend on the use of DLA and military warehouse space.

III. INVESTIGATIVE PROCEDURES

Results of the earlier study [1] indicated that the availability of steel and of several categories of skilled construction labor limit the shelters that can be constructed in most of the scenarios investigated. Two methods of obtaining additional steel for a shelter-building program are:

- Increase the production rate of steel, and
- Purchase and store the additional steel needed to make it immediately available any time surge period activities are initiated.

The earlier study revealed that additional steel production capacity is available but questioned whether or not the additional capacity can be activated in the short time associated with a surge period. Therefore, the material storage alternative appears to be the better approach, and the current study's objective is to determine whether or not material storage is a reasonable method of improving shelter-building capacity during a surge period. For that determination, the amount of steel available in the first month of a surge period was increased until the model indicated that the desired number of shelter spaces could be built or until another material became a limiting factor. Results of this series of analyses were then used to compute the quantities of materials that should be purchased and stored to successfully implement a risk area shelter program for each of the scenarios considered. When the stored materials become available in the first month of a surge period, they are actually available at any time they are needed throughout the surge period because the linear programming model carries unused materials from month to month. When the amount of materials to be stored had been determined, the cost of storage was added to the cost of the overall shelter construction program.

The shortage of construction labor was investigated in a similar way in that the availability of labor was increased until the model showed that the supply was sufficient to meet the need. However, sources of the additional labor were not treated quantitatively but are discussed qualitatively in Section V of this study.

In the earlier study, surge period lengths of 3, 6, 9, and 12 months were analyzed in combination with resource availabilities of 10, 15, 20, 25, 30, 40, and 50 percent of total annual production. Results of that study showed that shelter-building capacity varied linearly with respect to both surge period length and resource availability. A repeat analysis of several of the above scenarios based on the revised model no longer showed a linear relationship of shelter-building capacity with resource availability and surge period length. This nonlinearity suggests incompatibilities between the availability of materials and the availability of labor and equipment. The analyses were repeated with all constraints on the availability of labor and equipment removed to verify that the revised model was operating properly. Results of these runs were consistent with results of the earlier study, and the revised model was concluded to be operating properly.

From the earlier study, RTI concluded that up to 15 percent of the annual production of needed resources could be made available for shelter construction without economic penalties but that diversion of more than 15 percent of annual production would lead to price increases and could disrupt some segments of the construction industry. In light of these conclusions, the current study considers that 15 percent of resource production during a surge period would be made available for shelter construction and the remainder of the needed resources would be stored.

Several material storage options were investigated during the study. The first approach was to have the analytical model select the most cost-effective mix of shelter designs by removing constraints on the availability of resources. Other analyses were then conducted with selected combinations of resources made available without constraints. The resources were selected to correspond with requirements of specific shelter options. The storage requirements associated with each option were then determined.

Shelter options investigated were:

1. All resources unlimited,
2. Concrete unlimited,
3. Concrete and reinforcing steel unlimited,
4. Lumber unlimited, and
5. Structural steel unlimited.

Each option that produced a feasible solution (i.e., would provide shelter for 100 percent of the risk area population) was further analyzed to determine storage requirements for surge period lengths of 3, 6, and 12 months. Results obtained are described in the next section.

IV. RESULTS

The first analysis of each of the five options listed in the preceding section was to maximize the number of shelters that could be built. The outcome was considered acceptable if 100 percent of the risk area population could be sheltered. Findings of initial runs indicated that none of the options could provide shelter for the total risk area population because of labor shortages. The earlier study indicated that the availability of labor may be a problem in a surge period shelter-building program, and the revised model indicated that the labor shortage is magnified because of incompatibilities between the availability of materials and the availability of labor. Because explicit data were lacking, no quantitative solutions to the labor shortage problem were investigated. Instead, all computer analyses were repeated without constraints on the availability of labor. A qualitative discussion of the labor situation is included in Section V of this report.

Results of the computer analyses with no constraints on availability of labor showed that Options 1, 4, and 5 will permit shelters to be constructed for the entire risk area population, while Options 2 and 3 will not. Therefore, no further analyses were made of Options 2 and 3, but subsequent analyses were made of Options 1, 4, and 5 to determine the storage requirements associated with these options. Results are described in the following paragraphs.

A. Option 1--All Resources Unlimited

Subsequent to the initial analysis for Option 1, cost minimization analyses were made with all contraints removed from the availability of resources. Under these conditions, results should consist of the least

costly alternative for providing shelter. As expected, the 1,000-person, reinforced-concrete, rectangular shelter was identified as the least costly of the six designs considered in this study. Implementing this option for a shelter construction program would require storage of three or four materials, depending on the surge period length for which plans are made.

Table 1 identifies materials that would need to be stored, volume to be stored, cost associated with storage, and total program cost for the shelter construction program. Information is given in Table 1 for surge period lengths of 3, 6, and 12 months. The amount of each material to be stored has an inverse relationship with the surge period length for which a shelter construction program is to be implemented. As shown in Table 1, a shelter construction program under Option 1 could require storage of concrete, lumber, reinforcing steel, and structural steel and has storage costs of $3.4 to $4.1 billion and a total program cost of $45.1 to $45.9 billion.

Implementation of a shelter construction program within any of the time frames considered (3, 6, and 12 months) would require substantially more labor than would be available from 15 percent of the labor force. Table 2 shows the factors by which several categories of labor are short for Option 1. The shortage of steelworkers is severe for a 3- or 6-month surge period length and is substantial even for a 12-month surge period. Whether or not a labor deficit of this magnitude could be alleviated is questionable. Possible solutions are discussed in Section V.

B. Option 4--Lumber Unlimited

Cost minimization analyses with no constraints on availability of lumber yielded results that suggested the use of three shelter designs: the reinforced concrete arch, the steel dome, and the lumber version of the small

TABLE 1. STORAGE REQUIREMENTS--OPTION 1

	Material to be Stored (10^6 tons)					
Surge Period	Concrete	Lumber	Reinforcing Steel	Structural Steel	Storage Costs ($\$10^6$)	Total Program Costs ($\$10^6$)
3 months	305.7	5.3	14.0	1.6	4,148	45,912
6 months	287.8	3.3	13.8	1.2	3,888	45,652
12 months	252.0	0	13.5	0.6	3,379	45,143

TABLE 2. LABOR SHORTAGES--OPTION 1

	Labor Shortage Factors			
Surge Period	Laborer	Carpenter	Equipment Operator	Steel Worker
3 months	2.4	2.2	1.4	26.3
6 months	1.2	1.1	-	13.4
12 months	-	-	-	6.6

pole shelter. The first two designs would use materials that become available during the surge period, and the third design would depend mainly on lumber in storage at the beginning of the surge period. Table 3 shows the amount of lumber that would need to be stored to implement a shelter construction program in 3, 6, or 12 months and the storage and total program costs associated with this shelter option. The amount of stored lumber ranges from 98.0 to 116.9 million tons and the total cost of this option ranges from $61.7 to $63.8 billion, significantly more than for Option 1. Table 4 shows that the most severe labor shortage occurs with building laborers and that both laborers and carpenters are in short supply for all surge period lengths.

C. Option 5--Structural Steel Unlimited

The cost minimization analyses with no constraints on availability of structural steel favored a program that uses two shelter designs: the 1,000-person, reinforced concrete, rectangular shelter and the steel dome shelter. The reinforced concrete shelters would be constructed with materials that become available during the surge period, while the steel dome shelters would be built with structural steel from storage. Storage requirements and costs associated with this shelter option are contained in Table 5. Because of its substantially lower storage costs, Option 5 would cost less than would Option 1.

Table 6 shows the labor shortages that would be expected in conjunction with Option 5 and surge period lengths of 3, 6, and 12 months. The biggest shortage occurs in building laborers and for the 12 month surge period, laborers are the only labor category in short supply.

TABLE 3. STORAGE REQUIREMENTS--OPTION 4

Surge Period	Lumber to be Stored (10^6 tons)	Storage Costs ($\$10^6$)	Total Program Costs ($\$10^6$)
3 months	116.9	1,485	63,800
6 months	110.7	1,406	63,105
12 months	98.0	1,245	61,698

TABLE 4. LABOR SHORTAGES--OPTION 4

Surge Period	Labor Shortage Factors		
	Laborer	Carpenter	Electrician
3 months	23.3	5.9	2.4
6 months	11.4	2.8	1.2
12 months	5.4	1.2	-

TABLE 5. STORAGE REQUIREMENTS--OPTION 5

Surge Period	Structural Steel to be Stored (10^6 tons)	Storage Costs (\$$10^6$)	Total Program Costs (\$$10^6$)
3 months	23.5	299	42,952
6 months	23.0	292	42,936
12 months	21.8	278	42,903

TABLE 6. LABOR SHORTAGES--OPTION 5

Surge Period	Labor Shortage Factors				
	Laborer	Electrician	Equip. Oper.	Supervisors	Maintenance
3 months	12.0	2.8	2.1	3.0	5.8
6 months	6.0	1.4	-	1.5	2.9
12 months	2.9	-	-	-	-

V. CONSTRUCTION LABOR PROFILE

The labor force and employment structure in the U.S. construction industry differs markedly from that of U.S. industry in general. The workplace continually shifts in the construction industry because construction jobs at a given location are of limited duration and because contractors continually create and eliminate work crews and job organizations as tasks at a given site are completed. Job opportunities vary across seasons and geographical areas, locally, regionally, and, in some instances, nationally. Work groups change frequently and worker ties to individual employers are weaker than for U.S. industry in general.

This lack of attachment by individual workers to particular employers provides a variable-pool work force that is available to a wide range of contractors. Moreover, a construction worker frequently performs several functions (e.g., foreman, journeyman, and contractor) and may be employed on projects ranging from commercial buildings to homes to highways and other heavy construction.

The unpredictable nature of construction and the fluctuating quantity of active construction programs are most commonly attributed to market demand and the seasonality of many types of construction projects. Other factors include economic stability, or the lack of it, and unionization. Employers and unions in the construction industry are forced by the unusual nature and characteristics of employment and economic conditions to work more interdependently than many other industries in the United States.

Employment with a given construction project is normally short, and the employee-employer relationship is weak. However, employers are covered by collective bargaining agreements on an areawide basis extending over the time

period covered by the agreement, which provides a continuous relationship between the employer and the union. Given the intermittent nature of employment in the industry, the weak employer-employee relationship, and the fact that most employers are small relative to the industry, most employee training, wages, and other conditions are negotiated on an areawide basis, and most training is conducted by several different employers. Training programs in construction are therefore almost exclusively on the job (OJT), the cost shared by employer and employee. Such programs are critical for high-skill employment categories.

Within the contract construction industry, the numbers of total employees and the numbers of construction workers have increased most years for the last 25 years. The average annual employment in the contract construction industry grew from 2.885 million employees in 1960 to 4.015 million in 1973, almost half (1.988 million) by special trade contractors. The average annual number of employees declined by 50,000 in the contract construction industry in 1974 and again in 1975.

The unemployment rate in the construction industry is usually higher than that in other industries and is consistently higher than the rate for all industries. The average annual unemployment rate in the U.S. construction industry ranged from 6.0 to 15.3 percent over the 1948-74 time period, but the model unemployment rate is approximately 10 to 11 percent and the rate is over 10 percent for 14 of the last 20 years.

On the other hand, the average annual unemployment rate for all industries ranges from 2.9 to 6.8 percent from 1948 through 1974, but the rate for most years clusters in the 4.5- to 5.5-percent range. Of particular interest, construction unemployment is roughly twice that of all manufacturing

and durables manufacturing. The unemployment rate in the construction industry is normally higher than that in any other major industry, and the number of unemployed construction workers, on an average annual basis, constitutes over 10 percent of the unemployed in the United States.

Furthermore, craftsmen employed in the construction industry have a significantly higher unemployment rate than craftsmen employed in the economy in general or in manufacturing in general. Similarly, unemployment rates are higher for construction laborers than for nonagricultural and agricultural workers, other than migrant agricultural workers. It is generally believed that laborers in construction have higher unemployment rates than do craftsmen and skilled workers in construction.

It is not surprising that occupants of relatively easy entry and fairly rapid exit would exhibit inflated unemployment rates. Seasonal fluctuation in construction activity is the major contributing force to unusually high annual unemployment rates for construction workers. However, even during peak employment months of summer, construction workers suffer higher unemployment rates than do many other industry types. The differential between these rates is narrower in summer than in winter, especially in February. Some types of construction work are highly weather dependent, even during summer months, and additional unemployment may be the result of time lost between jobs. The number of workers employed in the construction industry may change by as many as 1 million workers during a single year.

Because of the highly variable demand for construction workers, large numbers of people work for short time periods in the industry and then move to more permanent employment in other industries. This trend and the fact that construction workers account for a large fraction of the total unemployed

workers at any time imply that there is a large pool of experienced construction labor available outside of workers formally employed in the industry at any given time. This labor pool could help alleviate the shortage of construction labor that is predicted for the shelter construction programs. Limitations on time and funds in this project have not permitted a quantitative evaluation of the labor situation.

VI. DISCUSSION AND RECOMMENDATIONS

Results of the analytical study associated with this project indicate at least three alternative surge period shelter construction programs for which material storage is a feasible way to augment the availability of resources. Any of the three alternatives could serve as a basis for plans to construct risk area shelters for the entire risk area population in as little as 3 months. The first alternative has the lowest overall material costs but also the highest storage costs, which makes the total costs under that alternative higher than for the third alternative. Materials that must be stored under the first alternative include portland cement for making concrete. According to North Carolina State University experts, the storage of portland cement for long time periods requires special packaging and is normally not recommended. For that reason, the first alternative may not be the best choice for shelter construction program plans.

The second feasible alternative requires storage of only one material: lumber. Although the storage costs of this alternative are relatively low, the total program costs are about 50 percent greater than for the other options. This alternative emphasizes the use of buried lumber shelters with a capacity of 12 people. These shelters may not be appropriate for all locations. This possibility and the high cost are two disadvantages of this alternative.

The third feasible alternative also calls for storage of only one material: structural steel. This alternative has the lowest overall program costs of the three and has the least severe labor shortage at all three surge period lengths considered. This alternative appears to offer the most advantages of the three.

Under all of the alternatives, the availability of labor is the most severe problem identified. This problem is intensified for the shorter surge period lengths. Although the labor supply available may be adequate at most times, identifying and using that labor may still be a problem. If serious consideration is given to implementing a material storage program in support of a shelter construction program that could be completed in less than a year, additional research should be devoted to the labor shortage problem.

A shelter construction program that uses stored materials offers at least one advantage over a program with no stored materials. Storage allows for maximum use of available labor by eliminating "down time" that may result from a lack of materials at the beginning of a surge period or between shipments of materials. In view of the projected labor shortages, this characteristic of a storage policy could contribute greatly to the success of any shelter construction program that is implemented.

VII. REFERENCES

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Kamath, R.V., and M. D. Wright
March 1981 (UNCLASSIFIED) 24 pages

This report describes a continuation of an earlier study of the feasibility and costs of providing all-effects shelters in risk areas for an in-place shelter plan and a population relocation plan. The results of the earlier study indicated that a minimum of 6 months and 50 percent of national production of reinforcement and plate steel would be required to provide shelters for the population of risk areas for an in-place shelter plan. The purpose of the study described herein was to determine if advanced purchase and storage of materials would be a realistic measure for improving surge period shelter building capability.

The results of the study show that there are three feasible programs for storing materials to support surge period shelter construction. Under the assumptions used in the study, the overall program cost is not significantly increased by the storage of materials. However, there may be severe shortages of labor to implement a surge period shelter program.

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